PRECAUTIONS TO REDUCE ASBESTOS HAZARDS

During this survey the Ministry of Defence (Navy) took steps to reduce the hazards associated with asbestos. These steps included a review of the use of asbestos, and where possible the introduction of substitute materials. The current uses of asbestos and the progress in finding substitute materials are summarized below.

Thermal insulation in machinery spaces

Calcium-silicate sections and plastics. Now supplied asbestos-free and recognizable by its yellow or pink colour. All calcium-silicate should be cut off-ship so far as is practicable. (Calcium-silicate containing up to 14 per cent asbestos is coloured white).

Amosite-asbestos sections and plastics. No longer used, replaced by calcium-silicate. A large number of existing ships are insulated with amosite: de-lagging operations will involve the full implementation of Naval Asbestos Regulations.

Self-setting asbestos finishing cement for high-temperature insulation

An asbestos-free substitute is now specified.

Asbestos cloth. Glass-cloth is now specified. Dust emitted from this cloth is an irritant but not a health hazard. Work is continuing to make this cloth less objectionable to handle.

Asbestos rope and twine. This has been deleted from specifications. Glass is now specified.

Asbestos mattresses. Mattresses of rocksil fibre covered with glass-cloth are now approved and in supply.

Local protection against fire

Asbestos millboard. This is now very little used and has been deleted from specifications.

Asbestos cloth. This is more frequently used, and a dust-suppressed cloth is now specified. No prospect is seen of finding a substitute fire-resistant material. Main applications are hangar fire-curtains, curtains in magazines, and protection in welding and burning operations. Magazines will be separately compartmented in new construction and at long refits of existing ships. Glass-cloth is not acceptable for these usages.

Fire protection in magazines where jet efflux presents a potential hazard

Resin-bonded asbestos fibre. No substitute material suitable for this purpose. Material is supplied by manufacturer to exact sizes required. There is therefore no health hazard in shipyard application.

Thermal insulation of hull structure

Sprayed limpet asbestos. Deleted from specifications. Mineral fibre marine board, which is asbestos-free, is now specified. Any ships still insulated with sprayed limpet

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asbestos will require full implementation of Naval Asbestos Regulations for de-lagging operations.

Blue-block asbestos or amosite board. Deleted from specifications. Mineral fibre marine board, which is asbestos-free, is now specified.

Asbestos fibre and cloth for pipe covering. Deleted from specifications. Replaced by polyurethane or mineral fibre preformed sections with canvas covering, which are all asbestos-free.

Acoustic insulation of hull structure

Asbestos fibre board. Deleted from specifications. Existing stocks are being kept for small repairs only. Replaced by mineral fibre resin bonded slab, which is asbestos-free.

Amosite asbestos. Deleted from specifications. Replaced by mineral fibre marine board.

Limpet asbestos board. Deleted from specifications. Replaced by perforated PVC sheet.

High-temperature jointing and packing materials

Asbestos fibre and compressed asbestos fibre. No substitute heat-resistant material is available. No health hazard in forms used in shipyard applications.

Bearing materials and brake-linings

Asbestos reinforced plastics. No substitute wear-resistant material is available. No health hazard except if these materials are ground or worked (no known requirement for this).

Bathroom and galley deck-coverings

Neoprene terrazzo. Asbestos-free neoprene terrazzo is now available. Dockyards and overseers have been informed that this is the only acceptable material.

Partition bulkheads

Compressed asbestos sandwiched between metal, plywood, plastic sheets, etc. Deleted from specifications, which now state that materials containing asbestos are not to be used. Steel, aluminium or plywood will generally be used, pending investigations into alternative asbestos-free materials.

Covers to cushions and mattresses in submarines

Asbestos cloth (not dust-suppressed). Deleted from specification. Fire-retardant foam mattresses now approved.

Code of practice

The precautions to be observed by all Dockyard employees working with asbestos were published as a Code of Practice and have been strictly enforced. They were formulated after careful study of working methods and were based largely on the experience gained from this environmental study.

These precautions are:

To isolate asbestos work, and to restrict entry to those properly protected.
To reduce the amount of dust created by asbestos work by improving work methods and the materials themselves.
To protect all workers whether they work directly with asbestos or not. Protection is based on the degree of risk, and workers are sub-divided into (a) Registered Asbestos Workers, those who work directly with asbestos, (b) Neighbourhood Workers, those not directly involved with asbestos, but employed near or with asbestos workers, (c) Management Visitors, those who pay short supervisory visits to places where asbestos work is proceeding.
To keep a register of all men directly employed on asbestos work. To ensure that Registered Asbestos Workers have regular medical supervision. These include sprayed asbestos strippers, laggers, asbestos storemen, and nominated boilermakers, joiners, shipwrights, sailmakers, plumbers, smiths and labourer cleaners.
To provide protective clothing adequate for the degree of risk involved.
To provide changing and washing arrangements.
To carry out regular dust sampling whenever asbestos is handled to ensure that the proper precautions are taken.

The regulations are summarized in Table 9 which shows that the protective measures are related to the degree of risk involved in various processes.

IMPROVEMENTS IN WORKING METHODS WHICH HAVE REDUCED ASBESTOS EXPOSURE

Removal of sprayed asbestos and pipe and machinery insulation will continue to be very hazardous as long as asbestos is present. There seems to be no practical way to wet the material without causing other disadvantages associated with removing and clearing away the debris. Efforts have therefore been concentrated on isolating the work and allowing access only to those men who are properly protected. Large areas of the ship surrounding the work point need to be closed to unprotected workers because the dust easily spreads from one compartment or deck to another. Protection of the worker includes impervious overalls, an air-fed respirator, or at least a positive pressure power respirator, and adequate changing and washing facilities.

Because very high concentrations of dust are to be expected when these materials are removed, dust sampling should be concentrated on the surrounding parts of the ship while the work proceeds to ensure that unprotected men are not at risk. Sampling should also be carried out after all the debris has been removed and after cleaning with industrial vacuum cleaners has taken place. It is important to continue sampling after other men have started working in the cleaned compartments so as to ensure that the cleaning has been efficient, and that no residues of asbestos remains to be made airborne again by the air-driven tools so widely used in ship repair work.

This sampling is done routinely in Naval Dockyards, and workmen are not allowed to work unprotected in compartments in which the asbestos fibre count is more than

TABLE 9. PRECAUTIONS FOR ASBESTOS WORK IN NAVAL DOCKYARDS

Type of work	Notices to be displayed	Protection: Registered asbestos worker	Protection: Neighbourhood worker	Protection: Management visitor
Sprayed limpet asbestos	Sprayed limpet asbestos work ENTRY PROHIBITED	Fully protected with impervious suit, gloves, boots. Issued 'underclothing'. Air-fed hood. Shower at end of forenoon and afternoon.	Not allowed entry (if vital, as for registered asbestos worker)	Visit to be of less than half hour (if longer, as for registered asbestos worker). Impervious suit, glove, boots, skull-cap. Approved respirator
Major delagging	Asbestos delagging NO ENTRY	Fully protected with nylon overall, gloves, boots, skull-cap. Issued 'underclothing'. Air-fed hood or approved respirator. Shower on completion of day or night shift.	As for sprayed limpet asbestos.	Visit to be of less than half hour (if longer, as for registered asbestos worker). Nylon overall, skull-cap. Approved respirator.
Major lagging; cutting of asbestos materials	Asbestos lagging NO ENTRY	As for major delagging	As for sprayed limpet asbestos.	As for major delagging.
Minor lagging; delagging	Asbestos work in progress	Nylon overall, skull-cap. Issued 'underclothing'. Approved respirator. Shower on completion of day or night shift.	No restriction on entry. Respirators available on loan	No restriction on entry. Respirators available on loan.
Lagging shop (covered by own regulations)	Asbestos shop NO UNAUTHORIZED ENTRY	As for minor lagging; delagging.	Respirators available on loan.	No restrictions on entry. Respirators available on loan
Asbestos stores	Asbestos store NO UNAUTHORIZED ENTRY	As for minor lagging; delagging.	Respirators available on loan	No restriction on entry. Respirators available on loan.

2 fibres/cm³. Similar sampling strategy is employed for the application of pipe insulation, and great emphasis is laid on efficient cleaning of debris both during and after work has finished. Compartments which are shown to produce dust concentrations of over 2 fibres/cm³ are cleaned again until satisfactory sampling results are obtained. For a 6-month period (May–October 1969) 343 samples in engine rooms showed less than 1 fibre/cm³, while 17 samples showed a mean of 2·9 fibres/cm³. In boiler rooms there were 273 samples less than 1 fibre/cm³, and 9 (mean 2·7 fibres/cm³) more than 1 fibre/cm³. In smaller compartments there were 327 samples less than 1 fibre/cm³ and 25 samples with mean concentration 31·8 fibres/cm³. These figures suggest that it is possible to reduce the asbestos dust concentrations to very low levels if energetic cleaning methods are employed, although these results also reflect the reduction in the amount of asbestos that is now being used in Naval ships.

Most of the existing insulation in ships, and some of the new materials still contain asbestos, and there will still be the problem of men working in compartments in which the insulation is incomplete and liable to be damaged. Until the protective layer of glass fibre cloth has been applied over the insulating sections, they are vulnerable to damage by tools, other equipment, or merely by men crawling over them to reach other work. Measurements have been made of asbestos dust concentrations created by men working in a boiler room in which the lagging had not been completed. Long running samples over the working shift showed general atmosphere concentrations of less than 2 fibres/cm³. The values for breathing zone long period samples were between 2–5 fibres/cm³, but some short samples taken when men were crawling over partly insulated pipes showed dust concentrations of 6–144 fibres/cm³. Men are therefore required to wear dust respirators when they are working on or close to pipes on which the friable insulating material is still exposed.

Table 6 shows that asbestos is no longer used for acoustic insulation so that joiners will no longer be exposed to the dust except when they remove existing material. They will wear air-fed respirators to do this work. Welders and burners will still use asbestos cloth to protect equipment from molten metal, but by using dust-suppressed cloth, and by disposing of it instead of chipping off slag, they will no longer create high dust concentrations. Sampling has shown that levels of less than 1 fibre/cm³ are produced if the cloth is used in this manner. The same applies to the use of dust-suppressed cloth for pre-heat welding techniques; welders are now instructed in the correct use of dust-suppressed asbestos cloth.

Asbestos mattresses are no longer used for insulation, so that the provision of dust extracting units in the mattress shop is no longer required. Mattresses are now made of glass fibre cloth filled with mineral rock wool. The problems of skin and mucous membrane irritation associated with the use of glass fibre cloth has been overcome by improvements in the weave of the cloth.

DISCUSSION

This survey has shown that very high concentrations of amosite, crocidolite, and chrysotile asbestos dust have existed for variable periods of time in ships being refitted in Naval Dockyards. High concentrations of asbestos dust have spread to

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parts of the ship in which unsuspecting men would have worked without respiratory protection. The data give some indication of what the dust concentrations in Naval Dockyards are likely to have been over the last 25 yr. and help to explain the prevalence of asbestos disease in Dockyard workers (SHEERS and TEMPLETON, 1968).

The dust concentrations in US Naval shipyards reported by FLEISCHER *et al.* (1946) and by MURPHY and FERRIS (1966) were very high, but these investigators sampled total dust and the proportion of asbestos fibre was small. The processes studied were mainly concerned with the application of pipe lagging. FERRIS (1968) reported dust concentrations of 7–130 mppcf during the removal of amosite asbestos insulation: this dust level is very high but the asbestos content was not stated. BALZER and COOPER (1968) also reported that ripping out insulating material caused high dust concentrations: 8·5 fibres/cm³ was the mean concentration for this process, and it is not clear in their report where this work was performed. It is likely that higher concentrations occur in the congested spaces aboard ship than in machinery installations ashore.

These reports mention the difficulty of making an accurate assessment of asbestos exposure for insulating workers. This difficulty is due to the variety of materials used, each containing a different amount of asbestos, and due to the intermittent nature of the work. Both of these factors help to produce widely different dust concentrations, not only between different processes, but also during the course of a particular process. Without continuous dust monitoring of every process it will not be possible to establish accurate estimates of time weighted dust exposures for insulating workers.

The BRITISH OCCUPATIONAL HYGIENE SOCIETY (1968) sub-committee report on Hygienic Standards for Chrysotile Asbestos Dust suggests that if exposure to chrysotile asbestos is limited to a time-weighted average concentration of 100 fibre yr/cm³ then it should be possible to reduce the risk of developing the earliest sign of asbestosis over a working lifetime to less than 1 per cent. That is an exposure of 2 fibres/cm³ for 50 yr, or 10 fibres/cm³ for 10 yr. Not enough is known about the effect of high exposures for short periods, so that it would not be acceptable to expose a person to 100 fibres/cm³ for 1 yr. The report advises that dust concentrations over 10 fibres/cm³ require the use of an approved dust mask, and that a higher standard of respiratory protection is required for concentrations over 50 fibres/cm³.

Technical Data Note 13, published as a supplement to the Asbestos Regulations by the DEPARTMENT OF EMPLOYMENT AND PRODUCTIVITY (1970), suggests that 2 fibres/cm³ for chrysotile and amosite asbestos is the dust concentration manufacturers and users of asbestos should aim to achieve if they are not to provide their workpeople with respiratory protection. For crocidolite asbestos this limit is 0·2 fibre/cm³ because of the association between this type of asbestos and mesothelial tumours.

From the present survey it is clear that all processes involving work with asbestos insulating materials in Naval Dockyards give rise to asbestos dust concentrations of more than 2 fibres/cm³. Many processes have dust concentrations of 50 fibres/cm³ or more.

Despite the improvements which have been made towards reducing the asbestos dust concentrations in ship repairing it is obvious that personal protection for the

workers will have to be provided for many years, and that constant vigilance will be required to maintain, and improve, on those standards of asbestos hygiene that have now been achieved.

Acknowledgements—This work forms part of the study of asbestos hazards in Naval Dockyards undertaken by the Medical Research Unit, HM Dockyard, Devonport, which is supported jointly by the Institute of Naval Medicine, Alverstoke, Gosport, Hants, and the Medical Research Council Pneumoconiosis Unit, Penarth. I am indebted to the Directors of both institutions, and their staff for help and advice in this study, and the Medical Director General (Naval) for permission to publish this report. Mr. D. SWEET of Devonport Dockyard was responsible for the evaluation of the dust samples. Table 9 is adapted from "Working with Asbestos" Ministry of Defence (Navy) 1970.

The data in this paper are from part of a thesis approved by the University of London for the degree of Doctor of Medicine.

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Exhibit 29

WORLD HEALTH ORGANIZATION

INTERNATIONAL AGENCY FOR RESEARCH ON CANCER

BIOLOGICAL EFFECTS OF ASBESTOS

Proceedings of a Working Conference held at the International Agency for Research on Cancer, Lyon, France, 2 – 6 October 1972

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BIOLOGICAL EFFECTS OF ASBESTOS

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The International Agency for Research on Cancer (IARC) was established in 1965 by the World Health Assembly as an independently financed organization within the framework of the World Health Organization. The headquarters of the Agency are at Lyon, France, and it has Research Centres in Iran, Kenya and Singapore.

The Agency conducts a programme of research concentrating particularly on the epidemiology of cancer and the study of potential carcinogens in the human environment. Its field studies are supplemented by biological and chemical research carried out in the Agency's laboratories in Lyon and, through collaborative research agreements, in national research institutions in many countries. The Agency also conducts a programme for the education and training of personnel for cancer research.

The publications of the Agency are intended to contribute to the dissemination of authoritative information on different aspects of cancer research.

The authors alone are responsible for the views expressed in the signed articles in this publication.

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Industrial uses of asbestos

K. V. LINDELL[1]

Much has been published in the medical journals concerning the geology, occurrence, types, mining, milling and manufacture of asbestos, thus these aspects will not be discussed here. Some mention has also been made of the industrial uses of asbestos, but the great number of these uses precludes any complete report on this subject in a paper which must be limited in length. However, there are some points made in previous presentations which require elaboration, and the "why" of the need of asbestos fibre in the world we live in should be presented. A brief explanation of the grading of asbestos fibre is given, and a listing of the characteristics of the principal fibres used, together with some important comparisons.

CLASSIFICATION OF ASBESTOS FIBRE

Asbestos fibre is often described as being graded according to length. Actually, no grade of asbestos has any one specific length, but is classified according to those fibres remaining upon a set of screens after a standard period of agitation. The Quebec Standard Testing machine has four boxes, with screen openings of 0.500 in., 0.187 in., 0.053 in., the fourth being a receptacle for the fines which fall through the screens. A one-pound sample of asbestos is agitated for 600 revolutions at 328 rpm, and the resulting fractions are weighed. The fibre is sold on a guaranteed minimum test of the various fractions.

To further illustrate the length variation, Tables 1, 2, and 3 show the general characteristics of the principal grades of amosite, crocidilite, and chrysotile, with their main uses. Most fibres contain fines which will pass through a 200 mesh screen, although

Table 1. Amosite grades

General classification	Grade: Penge mine	Grade: Welte-vreden mine	Grade: Kromel-lenboog mine	McNett test: +14 M %	McNett test: −100 M %	Surface area cm^2/g	Main use
Extra long	D.11			70	20	3000	Moulded insulation
Long	M	W3	K3	64	26	3500	Moulded insulation, general insulation and board products, asbestos cement pressure pipes
	S11			62	26	3500	
Medium	S22	SW	SK	59	26	4000	Insulating and fire resisting boards, refractory tiles
	S22/65			40	35	8500	
Short	S33	GW	GK	46	35	5500	Insulating and fire resisting boards, refractory tiles and asbestos cement
	S33/65			33	40	8500	
	S44			18	50	8500	
			RK	21	47	6000	Asbestos cement sheets and moulded products, plastic reinforcement
			6805	10	55	7000	

The values shown in the above table are typical test results and are not to be used as specifications.

[1] Chairman, Committee for Occupational and Environmental Health, the Quebec Asbestos Mining Association; Consultant, Institute of Occupational and Environmental Health, Montreal, Canada.

Table 2. Crocidolite grades[a]

General classification	Grade	McNett test		Surface area cm²/g	Main use
		+14 M%	−100 M%		
Long	C	94	4	1,000	Asbestos textiles
	A	90	7	2,000	Felts for reinforced plastics
Medium	S	67	26	6,500	Asbestos cement pressure pipes
	S80	62	30	10,000	
	2S	58	30	7,000	
	H	50	33	8,000	Asbestos cement sheets
	H80	36	43	10,000	
Short	C10	30	49	14,000	Asbestos paper
	WDS	33	43	9,000	Asbestos cement sheets

The values shown in the above table are typical test results and are not to be used as specifications.

Table 3. Chrysotile[a]

General classification	Grade	McNett test		Surface area cm²/g	Main use
		+14 M%	−200 M%		
Long	3R–3K	76	18	10,600	Asbestos textiles
Medium	4T–4K	43	31	7,700	Asbestos cement, pipes and sheets
Medium-short	5R–6D	20	44	8,900	Asbestos cement sheets, paper, friction materials
Short	7D–7R	4	69	11,800	Tile, friction materials, caulking, putties

[a] Typical Canadian chrysotile.

there are some fibres produced today that have negligible fines. These fines usually contain both fibrous and non-fibrous material; the ratio of fibrous to non-fibrous fines varies from one asbestos type to another. It would be useful to determine the proportions of respirable fibres in the various grades.

TEXTILES

Perhaps one of the oldest uses of asbestos fibre is in the manufacture of textiles. The flexibility and strength (Table 4) of asbestos, and above all its resistance to fire (Table 5) provide the world with a most unusual and useful product. From the legendary story of Charlemagne's "magic table-cloth" to its multitude of uses in our modern economy, asbestos has led the way in protecting man under the most hazardous conditions. Similarly, because of its resistance to physical, electrical and heat effects, the textile applications of asbestos range from wire and cable insulation to uses in motors and transformers. Since asbestos has exceptionally good resistance to nuclear radiation, to fungus, and to length reduction upon processing, it is superior in textile uses to almost all of the other mineral fibres.

Table 4. Comparison of tensile strengths of various materials

Type of material	Tensile strength (lbs/in²)
Ingot iron	45,000
Wrought iron	48,000
Carbon steel	155,000
Ni-Cr steel	243,000
Piano steel wire	300,000
Cotton fibre	73,000 to 89,000
Rock wool	60,000
Glass fibre	100,000 to 200,000
Chrysotile asbestos	450,000
Crocidolite asbestos	500,000
Amosite asbestos	350,000
Tremolite asbestos	75,000
Anthophyllite asbestos	240,000

Table 5. Effect of heat on tensile strength of Canadian chrysotile (crude)

	Tensile strength (lbs/in²)	Per cent of original tensile strength
Original crude—no heat	400,000	—
Heated 3 min at		
600 F	120,000	91.6
800 F	96,000	73.3
1000 F	78,000	59.5
1200 F	42,000	32.0

Asbestos yarns braided into various configurations have been used highly successfully as packing materials in pumps, pistons and so on; such braided asbestos products treated with a variety of saturants are extremely durable under rugged conditions of use. In such applications the resilient, soft, non-abrasive characteristics of asbestos are put to good use in keeping essential machinery operating efficiently and at low cost.

For the conditions prevailing in an internal combustion engine, no other fibre is as effective as is chrysotile asbestos in the mixtures used; it resists the attack of hot gases, hot oils, steam, hot water and anti-freeze mixes; and it is more resilient than other fibres—efficient jointing-sealing materials must be resilient. There is no conceivable health risk in the use of asbestos-based gasket materials.

The total amount of asbestos fibre used in the textile industry is relatively small compared to the total tonnage consumed. It is, however, an important use, since it also provides protective clothing and insulation covering for conditions where satisfactory substitutes have not yet been found. Also available today is a dust-suppressed cloth, made of yarn produced by a wet dispersion process.

FRICTION MATERIALS

Man's need for transportation is as old as civilisation itself; but, as his need for rapid transportation has increased, so have the perils he has brought upon himself. Next to fire and war, stopping motion represents perhaps mankind's greatest self-inflicted danger.

The ideal brake-lining has not yet been compounded. We know that it must have a high coefficient of friction for braking but that it must not score the brake-drum. It must be able to withstand the high temperatures which occur when the high energy of motion is transformed into heat; and it must not pass this heat inward or it would destroy itself too quickly. It must be ready to be used again, on short notice; all this without noise or other pollution. It has been shown that asbestos does provide good braking, without scoring the brake-drum. It disintegrates (only on the surface) to a powder, so that a new surface is presented immediately. It is ductile and soft enough to do all this without noise and with only a minute loss of material (material which has been transformed to an amorphous substance and is no longer a fibre). It does not permit the heat to be transferred inward to destroy other materials which may have been used as binders for the compound. It has proved strong enough to resist all the handling involved in its manufacture up until the stage at which it becomes a part of the finished brake-lining. It wears slowly; and above all permits brake-linings to be made economically and reproducibly time and again to demanding specifications, in order to ensure the utmost in safety in cars and in other moving vehicles in use today.

It is not surprising, then, that asbestos is a vital part of the composition of friction material. Its high strength provides a toughness necessary for suitable and dependable service, without any apparent risk to the general public.

Studies by the United States Public Health Service show that only a tiny fraction of the asbestos in brake-linings is released to the air as airborne particles in their original form as the brakes wear. Alternative reinforcements, such as glass fibre, have lower strength, low melting-points and cause damage to the brake-drum; steel wool has low availability, low strength, and causes damage to the drum; mineral wool has low strength and is brittle to the extent of limiting mixing processes. Other alternative materials, such as sintered metals and ceramics, have inconsistent behaviour at various temperatures; heat transference creates a risk of the brake fluid boiling. Asbestos fibre is the only reinforcing fibre which imparts consistent performance to friction linings and which provides frictional stability and fade resistance.

PAPER PRODUCTS

Asbestos paper products, ranging in thickness from a few millimetres to approximately ¼-inch, serve to protect man and his property in many ways. Because of their electrical resistance such products are used as insulation in transformers, electrical motors and as wire or cable wrappings. Their resistance to heat allows them to be used as protective layers in high-temperature devices such as furnaces, heaters, etc. When saturated with asphalt, asbestos papers provide a protective roofing which does not rot and which is extremely weather resistant. Used as a roofing underlay, asbestos felt provides protection against disastrous fires such as those which swept the West Coast of the United States a few

years ago. Their weather- and rot-resistance and their compatibility with asphalt allow asbestos felts to be used as protective wraps on metallic pipe-lines, which are otherwise subject to corrosive attack when buried underground.

While all of the man-made mineral fibres possess the non-burning characteristic of asbestos, none other of them possesses the ability to attract and retain binders and saturants as does chrysotile asbestos. The unique positive charge of chrysotile attracts and retains the negatively charged binder particles to the felted product. According to Woolery (1966), this characteristic of chrysotile asbestos also enhances the retention by cellulose papers of filler and pigment, thereby effecting a material cost reduction in one of the world's largest and most important industries.

ASBESTOS CEMENT PRODUCTS

Regardless of his location on this earth, man's need and search for adequate shelter and respite from the elements is rivalled only by his need and search for food and water. Asbestos cement products provide the world's population with safe, long-lasting, weather-resistant homes and places of work; their resistance to fire, weather, rot, rust or oxidation and destruction by rodents and insects is unparalleled among building materials. Asbestos has a great contribution to make to housing in developing countries, since the cement industry, which relies largely on indigenous materials, is always one of the first to get underway in a developing country. The introduction of an asbestos cement plant can, therefore, with the least disruption to the economy, produce large quantities of sheet for the roofs and walls of buildings. In developed countries, the use of such sheets remains an economic means of covering factories and buildings; and since there is no health risk involved in the handling of this type of material for this purpose it should continue to fulfil an important role in construction.

Simularly, asbestos cement pipes help to meet man's demand and need for water by providing strong, non-corroding, economical conduit systems; their smooth bore is maintained since they do not become encrusted. Asbestos is used in such products for several reasons among which are its high strength, its compatibility with cement systems, its ability to form felts or webs from aqueous slurries, and its resistance to cement alkalis and to physical attrition under manufacturing conditions.

Since the uses of asbestos cement are so widespread, it is not surprising that considerable effort has been made to find substitute materials which might be cheaper, or which could be found indigenously in the countries of manufacture. To date, such programmes have not been productive, or, at best, only partially successful. It is important therefore to assess those properties of asbestos which are responsible for its unparalleled performance in the construction industry.

Asbestos fibres have extremely high tensile strengths, which in most cases far exceed those of any other fibrous material. Zukowski & Gaze (1959) have shown that the varieties of asbestos used in asbestos cement products have average tensile strengths ranging from 440,000-600,000 lbs/in^2; they indicate in fact that under the most favourable circumstances, and with very short fibres, tensile strengths of nearly 900,000 lbs/in^2 may be obtained.

In the manufacture of asbestos cement products, cement is retained by asbestos fibres by both physical entrapping and chemical absorption. According to Biwas (1962) and Chatterji & Dhangal (1961), chrysotile fibre retains a greater amount of cement by chemical absorption than do the amphiboles; however, this property of chrysotile asbestos should be considered only a contributing attribute rather than the prime factor in the resulting high mechanical strengths of asbestos cement products. For example, tremolites provide only about 50 per cent of the transverse strength in asbestos cement sheets, probably due to the much lower tensile strength of this variety of asbestos and its lower absorption of cement. On the other hand, the particular structures of amosite and crocidolite cause these fibres to provide more bulk volume in both the dry state and in aqueous suspension than does chrysotile; and their surface properties have a vital effect in any manufacturing process employing a wet system. In asbestos cement manufacture, amphiboles complement chrysotile by improving the drainage rate and by dispersing the chrysotile fibres more effectively.

Most asbestos cement products are formed from wet slurry systems; because of their thin diameters and their flexibility asbestos fibres in an aqueous slurry felt together easily to form a web, which in turn entraps and retains the cement particles. Fibres such as mineral wool, basalt wool and glass wool are spicular in shape, have lower surface areas

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Table 6. Solubility of asbestos

Per cent loss in weight after re-fluxing for two hours in 25% acid or caustic

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Actinolite	20.31	12.28	20.19	20.38	9.25
Amosite	12.84	2.63	11.67	11.35	6.97
Anthophyllite	2.66	0.60	3.16	2.73	1.22
Chrysotile	55.69	23.42	55.18	55.75	0.99
Crocidolite	4.38	0.91	4.37	3.69	1.35
Tremolite	4.77	1.99	4.99	4.58	1.80

Per cent loss in weight at room temperature (26°C) for 528 hours in 25% acid or caustic

	HCl	CH_3COOH	H_3PO_4	H_2SO_4	NaOH
Actinolite	22.55	12.14	20.10	20.60	9.43
Amosite	12.00	3.08	11.83	11.71	6.82
Anthophyllite	2.13	1.04	3.29	2.90	1.77
Chrysotile	56.00	24.02	56.46	56.00	1.03
Crocidolite	3.14	1.02	3.91	3.48	1.20
Tremolite	4.22	1.41	4.89	4.74	1.65

and do not have the felting and cement retention characteristics so well demonstrated by asbestos. For these reasons, presently known manufacturing processes for cement products can utilise only limited amounts of these artificial fibres in place of asbestos without seriously and dangerously impairing the strength and quality of the product.

Alkaline conditions evolving in cement systems do not attack asbestos fibres (Table 6); this is not true of many of the synthetic or artificial mineral fibres. Slag wool fibres have a poor resistance to alkali, as do glass fibres of normal composition; and as a result asbestos cement products made with these types of materials deteriorate in strength with time. Recent publications discuss the potential use of special alkali-resistant glasses in cement products; however, the present cost of such fibrous materials far exceeds the performance:cost ratio of asbestos in the largest portion of the asbestos cement product line. The alkali-resistant glasses have not yet been tested for a period comparable to the normal life of an asbestos cement sheet; and it may well be that glass fibre suffers degradation several years earlier than does the sheet, an occurrence which could have dangerous consequences.

Finally some mention must be made of the resistance of asbestos to particle size reduction under all conditions of processing. Asbestos fibres are extremely resistant to length attrition, this being particularly true of the chrysotile variety. The brittle character of artificial fibres such as mineral wool, glass and others is well known; these materials cannot withstand the mixing, fiberising, pulping and slurry transport processes which are common to most industries. In this respect asbestos has few, if any, rivals in the field of reinforcing fibres (Table 7).

Table 7. Comparison of approximate fibre diameters

Type of fibre	Fibre diameter in micrometres	No. of fibrils in one linear inch
Human hair	40	630
Ramie	25	1015
Wool	20–28	900 to 1250
Cotton	10	2500
Rayon	7.5	3300
Nylon	7.5	3300
Glass	6.5	3840
Rock wool	3.5–7.0	3250 to 7040
Asbestos (chrysotile)	0.018–0.030	850,000 to 1,400,000

OTHER EQUALLY IMPORTANT USES

A complete story of the "why" of asbestos would need to include its indispensability in asbestos-reinforced thermosetting plastics, and similar uses, all for the same reasons.

As a further comment on substitutes, it should be pointed out that since we cannot be sure that the dust from some of the materials now being advocated as substitutes for asbestos materials is not the cause of latent disease, there is a strong argument for the use of materials for which, on the basis of a half a century's experience, a standard has now been established which enables us to prescribe the conditions under which they can be used with safety.

CONCLUSION

The industrial use of asbestos has unfortunately in a number of cases been accompanied by a record of industrial disease. Even though in many countries the development of dust control systems has considerably reduced this hazard, it is only in comparatively recent years that it has been appreciated that the handling of some of these materials may be hazardous. There is not time or space in this paper to discuss this aspect; however, it should be recognised that much progress has been made in developing methods of control which make it possible to continue to enjoy the benefits of this unique material without undue risk to the health of those who work with it.

SUMMARY

The paper attempts to present the "why" of the need for using asbestos. The classification of asbestos fibres and their general characteristics are discussed. Tables are included to demonstrate these characteristics.

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Exhibit 30

Asbestos and Disease

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TABLE 2-11 Continued

Grade	Type	Texture	Mark according to U.S.S.R. Standard January 1, 1952
	Russian Chrysotile		
1	Textile	Hard (coagulated)	J-1
2	Long shingle	Hard	J-2
		Semihard.	P-2
3	Shingle	Hard	J-3
		Semihard	PJ-3
			P-3
		Soft	M-3
4	Short shingle and paper stock	Hard	J-4
		Semihard	P-4
		Soft	M-4
5	Paper stock	Hard	J-5

[a] With kind permission of Reinhold Publishing Co., New York, and D. V. Rosato.

of clinical effects, notably pulmonary fibrosis closely resembling that produced by exposure to asbestos dust. These effects could be due to the contaminating asbestos, but the fibrous form of the talc itself may also play some part. Even the platelike crystals can be taken up by tissue phagocytes and are thus potentially reactive (327).

3

Mining, Milling, Manufacturing, and Use

MINING

The development of an asbestos ore body usually begins as an open pit operation, in which the shallow overburden and ore are removed by power shovels or bulldozers working along parallel or spiral terraces, with transportation of the ore by truck or train to a nearby mill. Where the ore body goes deeper, is surrounded by hard rock, or breaks up into separated seams, underground workings may be added with conventional mining practices of blasting, shovelling, and haulage as for other ores. The existing roadway system of the open pit may be used for the last part of the haulage or the ore may be conveyed by cable car, elevator, or carrier to the mill. Sorting and screening of the ore to get rid of coarse unwanted rock, usually but not always accomplished by mechanical means today, may be carried out at the mill site or on the way to the mill. All of these operations generate dust and call for consideration of control procedures to be described in Chapter 20. Details will be found in appropriate mining publications (e.g., 71, 108, 686).

MILLING

The ore, as it comes from the mine, consists of rock fragments varying in size from fine particles to lumps up to 3 ft in diameter. The hardness

TABLE 3-4

Asbestos Materials Used in British Naval Dockyards in 1967 (314)[a]

Asbestos materials: Dusty	Asbestos materials: Nondusty
Blankets	Cloth (treated)
Cement	Condenser packing
Cloth (untreated)	Sheets (compresses fiber)
Cord	Gaskets
Fiber	Oilproof jointing
Millboard	Compresses fiber jointing
Packing fiber	Graphited packing
Rope	Rings
Soft sound insulation	Compressed sound insulation
	Jointing strips
	Tape
	Tubing
	Twine
	Webbing
	Washers
	Coated electric wire
Mixed Materials	
Calcium silicate sectional lagging (up to 15% asbestos)	
Amosite sectional lagging (over 90% asbestos)	
Magnesia compound (up to 15% asbestos)	

[a] With kind permission of P. G. Harries and the publishers of the *Annals of Occupational Hygiene*.

("sand") such tiles. Mention has already been made of possible risk by brake liners and repairers.

Disposal of Wastes Containing Asbestos

At every point on the road from sampling of ore deposits through mining, milling, manufacture, and use of asbestos, wastes develop. The contents of that final depressing vista of civilization, the municipal dump, include their quota of asbestos. Sanitary land fill, once established, should reduce but not eliminate asbestos dust generation. In any case, the waste collectors are at risk. Unless adequate controls are imposed—and expensive treatment of inorganic, "nontoxic" wastes provokes little enthusiasm—asbestos dust will be dispersed over the surroundings and the general background count will rise over a still wider area. The origin of wastes up to the production of end products is

well described in the following section of the EPA report frequently cited in this chapter (231).

> The exposure in open-dumping sites of such diverse wastes as asbestos mine overburden, oversized masses of screened asbestos ore, asbestos mill tailings, emptied asbestos shipping bags, and the consolidated overspray of asbestos-containing insulation provides an opportunity for the entrainment and widespread dispersion of asbestos fibers into the atmosphere. Atmospheric emissions can also result from the open disposal of the material collected by gas-cleaning devices, from the open disposal of scrap pieces of insulating materials and asbestos-cement products that carry surface deposits of asbestos dust produced by fabrication and field installation operations, from the weathering in open dumps of even those materials in which asbestos is originally present in a bound condition, and from the disposal of emptied shipping containers for asbestos.

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